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Sixteenth day of December 2004

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PATENTS ACT 1990

PROVISIONAL SPECIFICATION FOR THE INVENTION ENTITLED:

"METHOD OF FORMING AND TESTING THE FORMATION OF AMORPHOUS METAL OBJECTS"

This invention is described in the following statement:

This invention relates to the construction of ferromagnetic parts for use in electrical circuits, in particular in electromagnetic ballasts, transformers, and inductors where the ferromagnetic material is made from ribbon like strips.

BACKGROUND

Amorphous magnetic metal (AMM) is a man-made material, which is usually for manufacturing reasons made in the form of ribbon. Molten metal is raised to a high temperature and quenched very quickly to prevent crystallisation while being cooled. One such commercially available product is Metglas™(Hitachi).

Such material in general has the following properties, high permeability, low coercivity, good temperature stability, low iron losses, operable at high frequencies, high Curie temperature and little or no magnetostriction.

However, this material has high tensile strength and is difficult to cut.

US Patent 6106376 is assigned to one of the applicants for this patent. That patent discloses a method for bonding AMM laminations to form a stack. The patent also discloses a method and means for shaping the stack, for example, by cutting, to form a bulk object such as a wound stator or a rotor of an electric motor.

Even if cutting is possible, there are no guidelines available as to how to construct various shapes of AMM for an intended purpose. For example, such as the shape of ballast for an electrical light circuit, or a core for use in transformers and choke elements.

The disclosure in this specification provides selected constructional guidelines and a way of testing the quality of the assembly of the magnetic core that is useable when manufacturing such cores. The methods described are readily useable in a commercial production environment.

BRIEF DESCRIPTION OF THE INVENTION

In a broad aspect of the invention, a method of forming a magnetic core from cut magnetic ribbons comprises the steps of:

a) partially loading one end of a stack of magnetic ribbon material into a former having an electrically conductive coil mounted thereon,
b) locating the free end of said stack of ribbon material into a position in said former opposite said fixed end; and
c) applying electric energy to said electrically conductive coil, so as to produce an electromagnetic force that draws the free and fixed ends of said magnetic ribbon material towards each other.

In a further aspect of the invention, the application of electric energy is achieved by discharging an electrical charge storage device for a predetermined time over a predetermined period at least a predetermined number of times.

In a further aspect of the invention, a method for testing for the completion of the assembly of a magnetic core from cut magnetic ribbons comprises the steps of:

a) measuring one or more electromagnetic characteristics including the instantaneous value of core current and voltage during the process of forming said core;
b) comparing a said characteristic with a predetermined value;
c) continuing steps a) and b) until the comparison falls within a predetermined range.

In a further aspect of the invention, other characteristics include flux linkage and inductance.

Specific embodiments of the invention will now be described in some further detail with reference to and as illustrated in the accompanying figures. These embodiments are illustrative, and are not meant to be restrictive of the scope of the invention. Suggestions and descriptions of other embodiments may be included within the scope of the invention, but they may not be illustrated in the accompanying figures.

Alternatively features of the invention may be shown in the figures but not described in the specification.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 depicts a shape of a ballast core for use in a lighting circuit made of AMM ribbon;

Figure 2 depicts fully constructed magnetic ballast made from AMM and various other parts;

Figure 3 depicts a stack of AMM laminations ready for insertion in a former for making magnetic ballast;

Figure 4 depicts two ends of the AMM lamination positioned in a former;

Figure 5 depicts partially constructed magnetic ballast;

Figure 6 depicts a capacitor discharging circuit used in the construction of a magnetic ballast; and

Figure 7 depicts sample voltage, current, flux linkage and inductance waveforms used to compare like waveforms generated during the construction of a magnetic ballast made of AMM.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

By way of example, only the manufacture of ballast for use in a lighting circuit using ribbons of AMM will be described in detail herein. The general techniques disclosed however, may have use in the construction of other articles, for example, transformers and chokes to name but a few.

Disclosed in this specification is a method for assisting the construction of the element made of AMM and for testing the quality of the assembly during construction of that element.

Figure 1 depicts a perspective image of the shape of a ballast core comprising two substantially square or c-shaped hollow forms (10, 12). Current carrying wires are yet to be wound onto the ballast core (as shown in cross-section in Fig. 2).

Opposite ends of the ribbons forming each c-shaped hollow of the core abut and are spaced apart by horizontal arms (16) of a cross-shaped member 14. While the vertical arms (18) of the cross-shaped members abut and space apart each c-shaped hollow form from the other.

Figure 2 depicts a cross-sectional view of the shape of a ballast core including the elements of Fig. 1 plus a non-conductive core 20 and the wire windings end-on (27). The magnetic ballast is designed to have predetermined gap typically occupied by a plastic member 14 (at the locations described and shown for Fig. 1).

The c-shaped hollow forms (10, 12) are made of several hundred laminated ribbons of micrometer thick AMM in the following manner.

There exist cutting arrangements that provide orthogonal or sloped cuts along the face of the stacked ribbon or along the side profile of the stacked ribbon. By way of example, the method and means disclosed in US Patent 6106376 can be used.

Each AMM ribbon needs to be pre-cut to allow for an inner ribbon in a c-shaped hollow form to be shorter than an outer ribbon. This can be done to approximate lengths as determined by experiment or calculation.

The final cutting of the ends that will eventually be located adjacent but separated by the arm of the plastic cross is done once the current step is completed.

During the cutting process, which may use water or a non-corrosive liquid as a carrier, contamination on and between laminations may occur. A cleaning and drying process can be performed if required. This could consist of the following process. Clamps are released and all the ribbons are cleansed in an alcohol bath. Alcohol will readily carry away contaminants but then dry without residue at room temperature.

Extreme care needs to be taken not to put any of the laminations out of order.

To realign the ends of the ribbons an alignment jig can be used.

Figure 3 depicts the cut ribbons 38 loosely clamped 40 at one end in an alignment jig 42. Gently tapping the ends forms them into a single plane.

This step in the process can be readily done manually judging by eye the conformity of the ends to a common plane. Clearly such a step could be mechanised and a laser or other alignment testing tools could be used to judge conformity of the ends to a required flatness.

Eventually once made into the c-shaped form, the top half of the ribbons 42a will be made to become adjacent to the now shaped end 42b. Likewise the bottom half 42c will become adjacent to the now shaped end 42d.

Laminations have now been formed into a suitable shape for folding into two adjacent substantially c-shaped cores suitable for acting as magnetic ballast for lighting devices as depicted in Fig 2.

Fig. 4 shows the two ends 42a and 42c separated by lower arm 18 of the spacer 14 (cross-shaped member) and the flat ends abutting the lower surface of arms 16.

Spacer 14 is located with a former 20 pre-wound with wires 27 as described previously. The arms 16 of spacer 14 will provide the required air gap between the ends of the c-shaped forms, and it is made of a non-conducting non-magnetic material which does not attenuate the magnetic flux passing across the airgap.

Having a spacer 40 incorporated into the former 20 is new as such a method of creating a magnetic ballast has not been available previously since such a need has not previously existed.

The next stage of the forming process involves bending the cut AMM ribbon laminations around the former 20. The free ends of the cut ribbons are inserted into the gap between the upper arm 18 of the spacer and the sides of the former. The arm 18 of spacer 14 serves to guide the insertion of the ends of the cut ribbons. Figure 5 displays this step partially completed.

Not surprisingly, this is a physically difficult step in the process as the laminations are not always fully compacted together and the space between former 20 and the vertical arm 18 of the space 14 is sized for compacted laminations.

The frictional sliding forces between adjacent laminations start to build up and multiply as the folding continues, and exerting pressure only on the outer laminations causes uneven pressure on the bundle of laminations itself. The uneven air gap shown in Fig. 5 is not acceptable and ideally, the finished product should resemble that depicted in Fig.2.

An uneven array of ends of the laminations in the finished product would adversely affect the inductance and other electromagnetic characteristics of the magnetic ballast.

The final step of the process replaces physical forces applied to the outer laminations with an electrical energy discharge that produces a magnetic attraction between the cut ends of the laminations that moves the laminations into place.

A large current (compared to the rated current of the ballast) is applied to the windings 22 of the ballast for a short period of time (1-10ms).

The current generates a magnetic force of attraction between the two ends of the laminations.

The magnetic attraction forces are great enough to overcome the mounting frictional resistance forces mentioned previously and the two free ends 42b and 42d of lamination bundles are drawn towards the two fixed ends 42a and 42c respectively.

Repeated applications of electromagnetic force may be required until the ribbon ends are fully adjacent the upper surface of arm 16 is producing a uniform gap that can be verified automatically by measuring the inductance of the winding.

Fig. 6 depicts one embodiment of a circuit providing the energising current pulse described above.

In Fig. 6 the device under test represents the equivalent circuit of the winding of the ballast, T1 is the charging control switch and T2 is the discharge control switch. C is a unipolar capacitor that stores electric energy. R is the bleed resistor, and L is a choke that limits the initial charging current of the capacitor and also reduces the current rating of the input rectifier shown as V_{dc}. The diode across the winding is a freewheeling diode.

When T1 is switched on, this device receives electrical energy from the mains power supply from rectifier (V_{dc}) and stores it in a large capacitor C.

When the capacitor is fully charged, switch T1 is switched off and T2 is switched on which allows the current to flow as a pulse through the ballast winding. This generates a large force that attracts the ends of the AMM ribbons together.

It is predicted that the rated current and voltage of the capacitor will be about 400 to 1000V and 40-50A respectively (for a 240V, 1A ballast). The capacitors are in the range of 10,000μF and their specification for use in a high voltage discharge application is critical.

To achieve an acceptably high voltage, more than one capacitor may be connected in series. However, in practice this can increase the total internal resistance, which may

absorb some of the discharge energy instead of delivering that energy to the winding. Therefore, the design of the multiple capacitor should consider such adverse affects.

As it is not always accurate or even sufficient to visually inspect the success of this step of the process, ie to ensure that the air gap formed is uniform, a repeatable and accurate testing technique has been developed.

The principle of electrically testing the formulation of the ends of the ballast core is based on directly measuring the instantaneous values of ballast current and voltage during the above capacitive discharge process. Data acquisition systems and custom written software is required to use the following information.

Voltage across the ballast winding can be given in the formula

$$v_b(t) = R_b i_b(t) + \frac{d\psi_b(t)}{dt}$$

where $v_b(t)$ is the instantaneous voltage, $i_b\,(t)$ is the instantaneous current through the winding, and $\psi_b(t)$ is the instantaneous flux linkage of the winding. Therefore at any instance of time, the flux linkage characteristic of the ballast can be determined by integrating the above equation over a time period. If the total voltage drop of the external components and the value of the initial flux linkage are included, the general flux linkage equation per phase can be given by

$$\psi_b(t) - \psi_b(0) = \int_0^t [v(t) - \Delta v - i_b(t) R_b] dt$$

Where Rb is the winding resistance, Δv is the total voltage drop including the switching device and connections, dt is the time interval, and $\psi_b(o)$ is the initial value of the flux linkage.

The above integration will be performed by the custom software, which determines the following characteristic about the ballast referring to Fig. 7. The characteristic waveforms obtained can then be used to verify the correctness of the assembly process. Software and associated hardware provides a fully automated assembly and electrical testing system, which can be used in a production line for creating magnetic ballasts of the type described.

Once the gap is made uniform the ends can be clamped into position by any convenient means and the magnetic ballast is ready for inclusion in a lighting device.

The use of AMM in the ballast will decrease power consumption in comparison to all existing devices.

DATED this 2nd day of December, 2003.

Adelaide Research and Innovation Pty Ltd &
Glassy Metal Technologies Limited
By their Patent Attorneys
MADDERNS

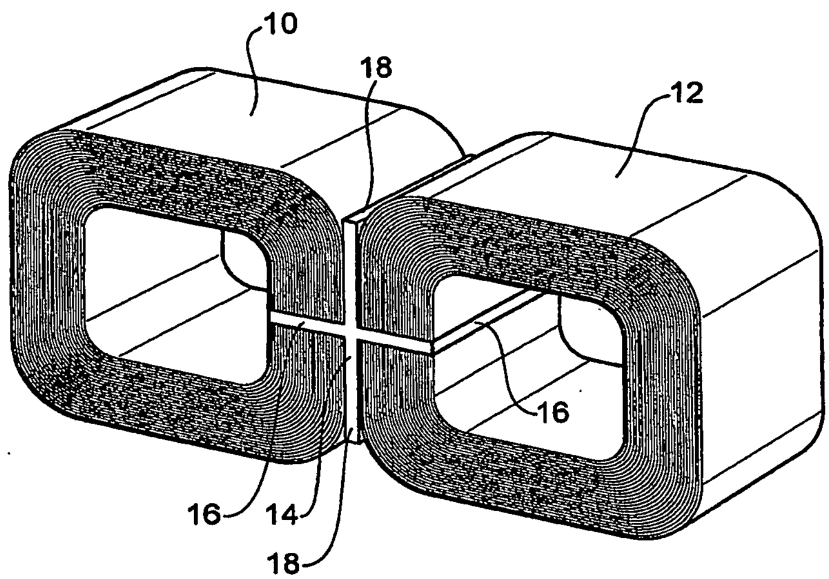

Fig 1

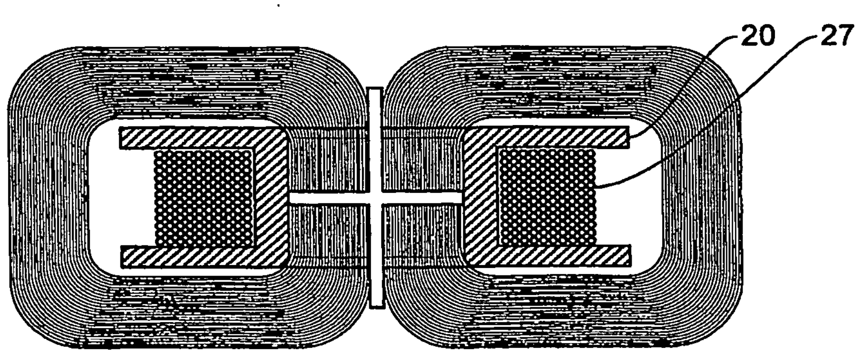

Fig 2

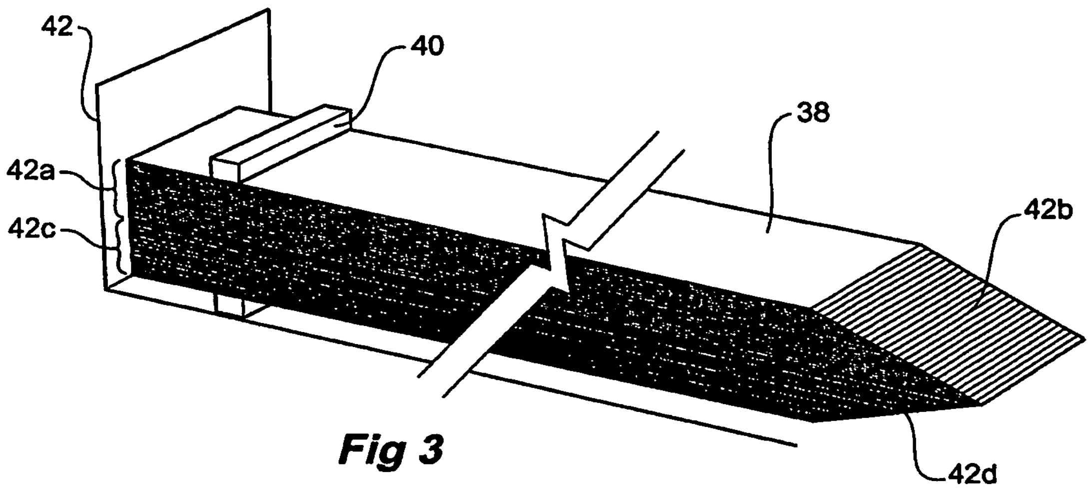

Fig 3

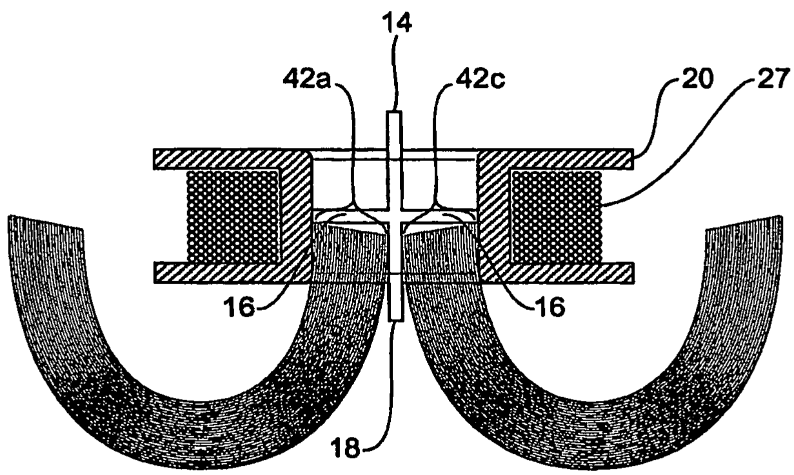

Fig 4

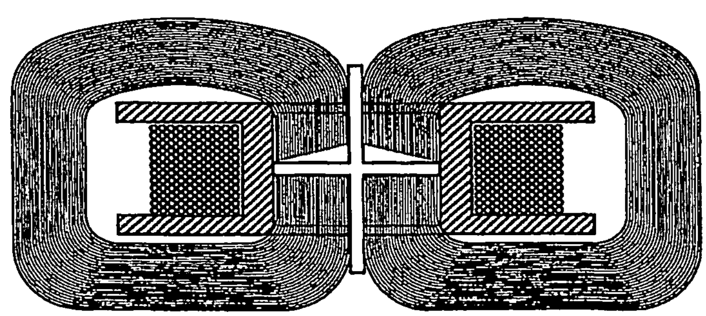

Fig 5

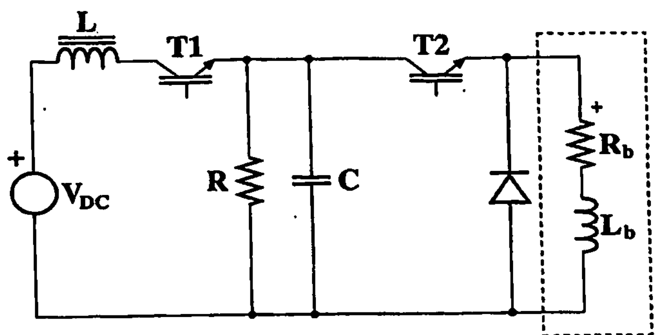
L
T1
T2
+
V_{DC}
R
C
+
R_b
L_b

Fig 6

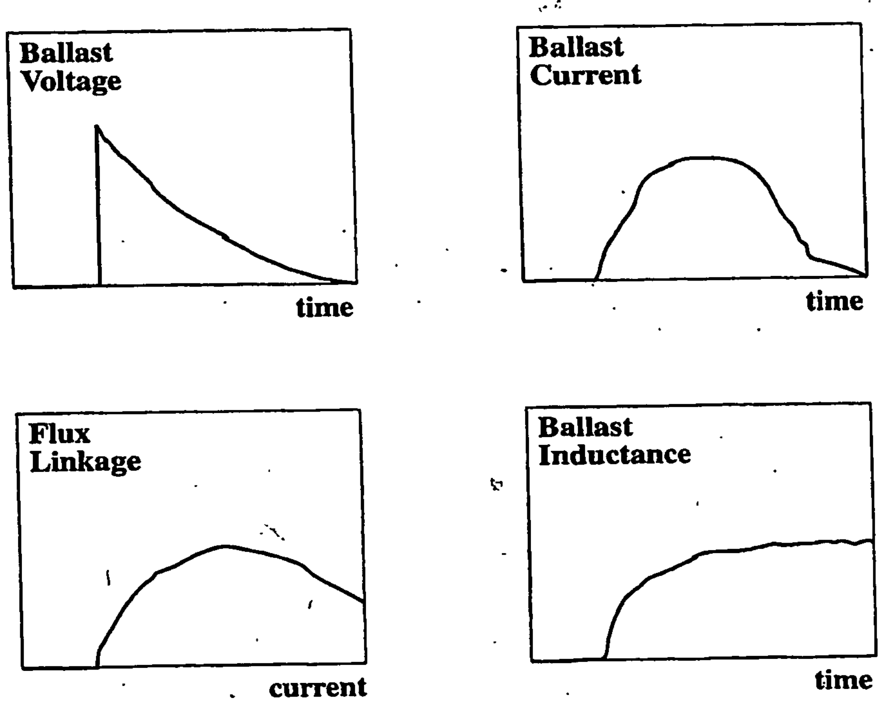
Ballast Voltage
time
Ballast Current
time
Flux Linkage
current
Ballast Inductance
time

Fig 7

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